NESTING SUCCESS OF GRASSLAND BIRDS IN FRAGMENTED AND UNFRAGMENTED LANDSCAPES OF NORTH CENTRAL SOUTH DAKOTA

BY

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NESTING SUCCESS OF GRASSLAND BIRDS IN FRAGMENTED VS. UNFRAGMENTED LANDSCAPES OF NORTH CENTRAL SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

NESTING SUCCESS OF GRASSLAND BIRDS IN FRAGMENTED AND UNFRAGMENTED LANDSCAPES OF NORTH CENTRAL SOUTH DAKOTA

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Abstract. Decline of grassland bird species has frequently been linked to habitat loss and fragmentation. A large amount of remaining native prairie is in the form of grazed pastureland; however, few studies have focused on assessing pastureland as habitat. While studies have found that species occurrence, density and breeding success is higher in large, unbroken habitat patches, the surrounding landscape likely plays an important part in habitat quality. The main objective of this study was to assess the nesting success of grassland birds in relation to habitat patch size and the composition of the surrounding landscape. I evaluated nesting success in moderately grazed native pastures in north central South Dakota within the following categories: 1) small patch area (<50 ha) surrounded by <40% grassland; 2) small patch area (<50 ha) surrounded by >50% grassland; 3) large patch area (>100 ha) surrounded by <40% grassland; and 4) large patch area (>100 ha) surrounded by >50% grassland. I used the nest survival model in program MARK to determine nest survival probabilities as a function of vegetation, patch and landscape variables. I also used logistic regression to construct models to evaluate the influence of vegetation, patch and landscape variables on the likelihood of nest parasitism. The most common species found were the chestnut-collared longspur

(*Calcarius ornotus*); western meadowlark (*Sturnella neglecta*); grasshopper sparrow (*Ammodramus savannarum*); savannah sparrow (*Passerculus sandwichensis*); ring-necked pheasant (*Phasianus colchicus*); and dabbling ducks (*Anas spp.)*. Response to landscape and patch variables varied among species. Larger patches were positively correlated with daily survival of chestnut-collared longspur and dabbling duck nests. Parasitism rates of savannah and grasshopper nests also decreased in large patches compared to small. Nest success rates for western meadowlarks were highest in small patches surrounded by high percent grass. Daily nest survival rates for western meadowlarks, savannah sparrows and grasshopper sparrows were higher in landscapes with >50% grassland habitat. Management recommendations include continued research into the effects of fragmentation on nesting success and also on predator activity, preservation of large, unbroken tracts of native prairie, and, where large tracts are unavailable, preservation of smaller prairie patches, especially those in high-percentage grass landscapes.

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CHAPTER 1 - INTRODUCTION AND LITERATURE REVIEW

Grassland Bird Decline

Analysis of the North American Breeding Bird Survey showed a general decrease in populations of grassland birds between 1966 and 1996 (Peterjohn and Sauer 1999). Specifically, 13 species showed decline, 9 species showed no change, and only 3 species showed an increase (Peterjohn and Sauer 1999). In South Dakota, the Breeding Bird Survey showed 15 grassland species declined between 1980 and 2005 (Sauer et al. 2005). Significant ($p \leq 0.05$) declines per year were exhibited by chestnut-collared longspurs (*Calcarius ornatus*) (-10.8%), lark buntings (*Calamospiza melanocorys*) (-5.0%), and grasshopper sparrows (*Ammodramus savannarum*) (-4.4%) (Sauer et al. 2005).

Decline of grassland birds is often attributed to habitat loss and fragmentation (Herkert et al. 1994). Native prairie, especially tallgrass prairie, has been lost at a far greater rate than any other ecosystem in North America, with only one tenth of 1% remaining in some states and provinces (Samson and Knopf 1994; Higgins et al. 2002). Much remaining grassland is represented by pastureland. A mosaic of lightly to heavily grazed grassland can provide habitats for a variety of species which have declining populations, including western meadowlarks, grasshopper sparrows, and chestnut-collared longspurs (Ribic and Sample 2001; Renfrew 2002; Salo et al. 2004; Bakker 2005). The continued decline in many grassland bird species in the Midwest and northern Great Plains is linked to the increasing pasture acreage that is being converted to row crops (Herkert et al. 1996; Higgins et al 2002; Renfrew 2002). Higgins et al. (2002) estimated that 14% (1.4 million ha) of remaining rangeland in South Dakota has been converted to cropland in the past 20 years.

In addition to the large expanses of prairie converted to cropland, remaining prairie has been degraded by the intrusion of exotic grasses and forbs, overgrazing, and succession to shrub land due to invasion by woody species (Grant et al. 2004; Lloyd and Martin 2005). For instance, Scheiman et al. (2003) found savannah sparrow and grasshopper sparrow densities to be lower in areas of abundant leafy spurge (*Euphorbia esula*) as compared to areas with less leafy spurge, thus concluding that "changes in vegetation structure caused by introduced plants can alter resource availability and hence bird community composition". While privately owned prairie fragments are often overgrazed (Higgins et al. 2002), many tallgrass prairie fragments on publicly owned sites are dominated by exotic species such as Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and quackgrass (*Elymus repens*) (Higgins 1999). This kind of habitat degradation plays a key role in the decline of some grassland bird species. For instance, Lloyd and Martin (2005) found that chestnut-collared longspurs nesting in monocultures of Asian crested wheatgrass (*Agropyron cristatum*) in eastern Montana had lower reproductive success than longspurs nesting in native habitat in the same area. Woody vegetation has also been shown to decrease occurrence, density and nesting success of several grassland bird species (Bakker 2003).

Patch Size and Edge Effects

Many prairie nesting species have been shown to be area-sensitive, meaning that occurrence, density and/or nest success is higher in large versus small patches (Herkert 1994; Winter and Faaborg 1999; Ribic and Sample 2001; Bakker et al. 2002). Examples of species shown to be area-sensitive include northern harrier (*Circus cyaneus*), sedge wren (*Cistothorus platensis*), clay-colored sparrow (*Spizella pallida*), grasshopper sparrow, LeConte's sparrow (*Ammodramus leconteii*), Baird's sparrow (*Ammodramus bairdii*), and savannah sparrow (*Passerculus sandwichensis*) (Herkert 1994; Winter et al. 1999; Johnson and Igl 2001; Bakker et al. 2002). Similarly, DeJong et al (2004) found increasing density of GRSP in larger patches in the xeric mixed prairie of western SD.

In some cases, the same species may display area sensitivity in one geographic region but not in another (Johnson and Igl 2001; Bakker et al. 2002). For instance, Johnson and Igl (2001) found that red-winged blackbirds (*Agelaius phoeniceus*) used larger habitat patches in Fallon County, Montana, but favored smaller patches in McPherson County, South Dakota. Similarly, in a survey of grassland birds throughout eastern South Dakota, Bakker et al. (2002) found that savannah sparrows were area sensitive in the tallgrass region but not in the mixed grass region. Clay-colored sparrows have been found to prefer smaller patches in native prairies (Johnson and Temple 1986), but larger patches in CRP fields, possibly due to the increased presence of shrubs, their preferred nesting substrate, in the native patches (Johnson and Igl 2001). Western meadowlarks occurred in lower densities in smaller patches of tallgrass prairie (Bakker 2002), but other studies have been inconclusive regarding area sensitivity of this species (Knick and Rotenberry 1995; Johnson and Igl 2001). Sedge wrens have been found to be area-sensitive (Johnson and Igl 2001), but Bakker et al. (2002) found that sedge wrens and clay-colored sparrows used smaller patches as well as larger ones if those patches were surrounded by high proportions (≥ 60% within 1600 m) of grassland.

The size and shape of a habitat patch has also been shown to influences avian productivity. Smaller grassland patches adjacent to areas of very different habitat type, called “hard” edge (i.e., woods, rowcrops), showed increased rates of predation and nest parasitism by brown-headed cowbirds (*Molothrus ater*) (Johnson and Temple 1990; Herkert et al. 1994; Winter and Faaborg 1999; Winter et al. 2000; Heske et al. 2001). Edges acted as predator corridors, allowing predators such as red fox (*Vulpes vulpes*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*) and opossum (*Didelphis virginiana*) greater access to nests (Herkert et al. 2003). In addition, rates of parasitism by brown-headed cowbirds were higher along habitat patch edges than in the interior of the habitat patch (Winter et al. 2000).

Predation is a major reason for nest failure in many studies (Martin 1993; Pietz and Granfors 2000; Winter et al. 2004). Predator communities and behavior are therefore central to understanding patterns of nest mortality, including the effects of patch size and landscape attributes (Skagen et al. 2005). Mid-sized predators such as skunk and fox frequent wooded edges more than roads or agricultural fields (Winter et al. 2000); therefore, areas where habitat patches are bordered by roads and crops (with no associated woodlands) rather than woodlands may exhibit less of an edge effect and therefore less of a patch size or landscape effect.

The edge effect may not be as prominent in smaller habitat patches (≤ 64 ha) as in larger ones because smaller patches have little or no interior habitat; the entire patch is, in effect, edge habitat (Pasitschniak-Arts et al. 1998). Pasitschniak-Arts et al. (1998) found nest success for mallard (*Anas platyrhyncos*), gadwall (*Anas strepera*), and blue-winged teal (*Anas discors*) in smaller patches (≤ 64 ha) was not influenced by proximity to habitat edge in an intensively farmed region of south-central Saskatchewan. However, in a previous study involving larger (> 200 ha) patches, Pasitschniak-Arts and Messier

(1995) did detect an edge effect, where more nests toward the center of the patch were successful than were nests closer to the patch edge.

Grazing may also reduce the degree of edge effect, even for larger patches. In actively grazed pastures in southwestern Wisconsin, Renfrew et al. (2005) found that, while some species avoided nesting near edges, there was little difference in nest success between nests near edges and those more interior. This lack of edge effect may be due in part to trampling by cattle, which alters the natural vegetation patterns so that predators can move more freely throughout the pasture (Renfrew et al. 2005).

Another variable that can affect avian productivity and abundance is degree of similarity of adjacent land to the habitat patch. While “hard” edges have clearly been shown to decrease nest success (Johnson and Temple 1990; Rodewald and Yahner 2001), “soft” edges, where the adjacent landscape is similar to the habitat patch, do not seem to have as negative an impact. For instance, Bollinger and Gavin (2004) found nest success of bobolinks (*Dolichonyx oryzivorus*) was not negatively affected by proximity to the edge of adjacent old fields or pasture, but forest edges did appear to have a negative impact on bobolink nesting success.

Landscape Effects

Factors other than patch size and edge influence avian abundance and productivity, including vegetation structure within the habitat patch as well as vegetation and landscape composition surrounding the patch (Johnson and Igl 2001; Ribic and Sample 2001; Bakker et al. 2002). For example, Bakker et al. (2002) found that, after removing the effect of local vegetation, grassland abundance surrounding a habitat patch was a better indicator of occurrence for sedge wrens and clay-colored sparrows in eastern

South Dakota than was patch size. Both species utilized small as well as large-sized grassland fragments when the fragments were surrounded by high proportions of grassland (Bakker et al. 2002). Ribic and Sample (2001) found that bobolink and eastern meadowlark (*Sturnella magna*) density in south-central Wisconsin was affected more by landscape than by local variables. Renfrew (2002) found savannah sparrow and grasshopper sparrow densities were more associated with landscape variables, but bobolink and eastern meadowlark densities were more affected by vegetation structure (a local variable).

Landscape composition can change how edges may affect nest success. Recent studies have examined the effect of landscape composition on duck nest survival in North Dakota (Horn et al. 2005; Stephens et al. 2005), Canada (Greenwood et al. 1995) and across the Prairie Pothole Region (Reynolds et al. 2001). Horn et al. (2005) found daily survival rates of upland-nesting duck nests to be higher in landscapes containing a higher percentage of grass (45-55% grass) than in low-percentage grass landscapes (15-20% grass) in central North Dakota. Phillips et al. (2003) determined that red fox and striped skunks foraged differently depending on the percentage of grass in the landscape, which may have led to increased duck nesting success in high-percentage grass landscapes in North Dakota. In the Prairie Pothole Region of the U.S., Reynolds et al. (2001) found a positive correlation between the nesting success of ducks in Conservation Reserve Program (CRP) fields and the amount of perennial grass cover surrounding the CRP fields.

Only one study, conducted in an intensively farmed region of Iowa, has examined the effect of landscape composition or patch size on nest success of ring-necked pheasants (Clark et al. 1999). In this study, the authors found that pheasant nest success was higher in larger habitat patches (≥ 15 ha), and concluded that several grassland patches within the nesting home range would provide more productive habitat than a single large patch**.**

Nest Success

Avian density alone may not be a reliable measure of habitat quality (Van Horne 1983; Vickery et al 1992). In a review of 109 published cases involving 67 different species, Bock and Jones (2004) found that avian density was sometimes negatively associated with reproductive success, most often in areas of high human disturbance and also in highly territorial species. Other studies have also shown a negative correlation between nest success and avian abundance. For instance, in a study of black-throated sparrows (*Amphispiza bilineata*) in southern New Mexico, Pidgeon et al. (2003) found the highest density of sparrows in mesquite (*Prosopis spp.*) savannas, despite very low reproductive success in those same areas. The authors attributed this to the loss of understory grasses due to heavy livestock grazing. In fragments of native tallgrass prairie in southwestern Missouri, Winter and Faaborg (1999) found that only greater prairie chickens (*Tympanuchus pallidicinctus*) and Henslow's sparrows (*Ammodramus henslowii*) were area-sensitive as far as abundance; however, when nesting success was taken into account, dickcissels (*Spiza americana*) were also found to be area-sensitive, having lower reproductive rates in smaller areas despite not being any less abundant in those areas. Furthermore, recent studies have found that factors which affect avian occurrence and abundance are not necessarily the same factors that affect nesting success (Winter and Faaborg 1999; Winter et al. 2006). For instance, Winter et al. (2006) found several factors, including patch size, percentage of shrubs and trees in the landscape, and region, influenced avian density in tallgrass prairie in Minnesota and North Dakota. However, none of these factors were found to affect ness success.

Objectives

The main objectives of this study were to examine the effects of local vegetation structure, habitat patch size, and surrounding landscape composition on the nesting success of grassland birds in grazed pastures of untilled native sod in north central South Dakota. I hypothesized that nest success would be higher in larger size habitat patches (> 100 ha) and in patches that have more grassland habitat surrounding them (> 50% grass within 1600 m of the habitat patch).

I predicted that responses to local vegetation, patch, and landscape variables would vary among species. Specifically, chestnut-collared longspur nest success has been shown to be affected by vegetation (Lloyd and Martin 2005), so I predicted local vegetation variables, such as visual obstruction, grass height, and litter depth, would affect nest success. Patch size has been shown to have little affect on nesting success of savannah and grasshopper sparrows (Winter and Faaborg 1999; Davis et al. 2006), despite the fact that some studies indicate higher abundance and occurrence in larger patches (Herkert 1994; Bakker et al. 2002). I therefore predicted that these two species would have a stronger response to vegetation variables than to landscape and patch size variables. Western meadowlarks have shown little response to patch size or landscape variables (Knick and Rotenberry 1995; Johnson and Igl 2001, but see Bakker et al. 2002), so I predicted nest success for western meadowlarks would be more influenced by local (vegetation) variables. Waterfowl nest success has been found to be higher in large patches (Ball et al. 1995; Sovada et al. 2000) and in high-percentage grass landscapes (Horn et al. 2005), so I expected similar results in my study. I also expected duck nest success to be associated with nest cover (local vegetation). Based on Clark et al.'s (1999) study, I expected ring-necked pheasants to have higher nest success in large patches and in high-percentage grass landscapes.

CHAPTER 2 – STUDY AREA AND METHODS

Study Area

The state of South Dakota includes 199,730 km^2 of land extending from longitude 96^o 30'W to 104^o W, and from latitude 43^o N to near 46^o N. The Missouri River runs from north to south, dividing the state into two nearly equal halves. The eastern half of the state is characterized by glaciated topography, and includes three major physiographic divisions; the Prairie Coteau, the James River Lowland, and the Missouri Coteau (Johnson et al. 1995).

This study was conducted in north central South Dakota, within four counties in the Missouri Coteau area: McPherson, Edmunds, Campbell, and Walworth (Figure 1). This region is dominated by rolling topography, mixed-grass prairie and numerous pothole-type wetlands. Common grass species of the northern mixed grass prairie include western wheatgrass (*Pascopyrum smithii*), big bluestem (*Andropogon gerardii*), porcupine grass (*Stipa spartea*), and needleandthread (*Stipa comata*). Common forb species include cudweed sagewort (*Artemisia ludoviciana*), silverleaf scurfpea (*Psoralea argophyllia*), and prairie coneflower (*Ratibida columnfera*) (Johnson and Larson 1999). Tillage agriculture and livestock grazing make up the majority of land use (Bryce et al. 1998). Elevation is between 503 m and 640 m (Bryce et al. 1998). Average annual precipitation is 44 cm: average minimum summer temperature is 10^o C, and average maximum summer temperature is 28^o C (High Plains Regional Climate Center 2006).

Site Selection

Habitat patches were selected nonrandomly using aerial photographs and on-site validation (DeJong 2000; Lloyd and Martin 2005) to reflect differences in patch size and surrounding landscape while keeping vegetation structure similar. Landscape composition within 1600 m of each study site was determined from aerial photography and ground truthing. Sites were grouped into four different categories: Type 1 - small (<50 ha) patch surrounded by < 40% grass; Type 2 – small patch surrounded by >50% grass; Type 3 – large (>100 ha) patch surrounded by < 40% grass; and Type 4 - large patch surrounded by > 50% grass (Table 1). A patch was defined as the area contiguous with the site that was the same cover type and condition as the site (Bakker 2000; Bakker et al. 2002). For instance, the border of a pasture and an adjacent tilled crop field would define a patch boundary. A border with a semi-permanent or permanent wetland would define another. I did not use temporary wetlands to delineate patches, nor did I use fence lines unless the cover type and condition changed across the fence. I did use roads and other man-made obstacles as patch boundaries (Bakker 2000; Bakker et al. 2002). Surrounding land cover that was considered grassland habitat included pastureland, CRP, and hay fields. In order to control for vegetation structure among the patches, only untilled native prairie patches with light to moderate grazing pressure were chosen. Both public and privately owned lands were included. There were very few trees in the area of our study, and no patch used in our study contained or was bordered by woods.

Twenty different sites were searched for nests during two field seasons. These included: 6 Type 1 patches (Scheutzel, Malson 2, Davis North, Davis 4, Kessler, and Stevens); 9 Type 2 patches (Ohio Trucker, Davis 3, Bieber, Biel, GFP, Weller, Ordway

House, Ordenbach, and Kirschmann); 2 Type 3 patches (Feinstein and Beyer); and 2 Type 4 patches (Ordway and Ordway 2) (Table 2). Equal areas were searched for nests in each patch type (Table 2).

Avian Surveys

Avian surveys were conducted once at each site using a fixed-width belt transect to determine presence and abundance of avian species (Wakely 1987). Surveys were conducted between 6:00 and 10:00 am along a 200-m transect placed near the center of each site. An observer walked slowly along the transect line and recorded the sex and species of each bird heard and/or seen within 50 meters of each side. Surveys were conducted in mid-June to minimize the possibility of migrants or young birds that could not be distinguished from their parents (Ralph et al. 1993). Surveys were not conducted when it was raining or windy (>10 km per hour) as these conditions may negatively affect bird activity or observer ability (Ralph et al. 1993). Equal area sampling (i.e., one transect per patch) was used regardless of patch size in order to avoid issues of passive sampling (Connor and McCoy 1979).

In order to keep observation methods as consistent as possible, one individual conducted all surveys. The observer was trained before the first field season by studying the Cornell Guide to Birds of North America, which contains recorded bird songs and photos of bird species together on a computer CD (Diehl et al. 2002). Time was also spent practicing bird identifications in the field prior to the first day of fieldwork. Because this method of surveying is not appropriate for waterfowl or upland game birds, only passerines were recorded.

Site Vegetation Measurements

Vegetation was surveyed in mid-June along the bird survey transect at each site. A modified Robel pole (Robel et al. 1970) was used to measure vegetation obstruction and height at four stations (every 50 m) along the 200-m bird survey transect in each patch. Visual obstruction readings were taken at the highest point where vegetation limited the visibility of the pole by 100% at a sighting height of 1 m from a distance of 4 m (Robel et al. 1970). Four readings to the nearest 0.25 dm were taken at each station from each of the four cardinal directions around the pole.

The tallest grass, forb, and woody vegetation height was measured to the nearest dm once at each station within 4 m of the pole. Litter depth was measured to the nearest mm using a standard metric ruler inserted into the litter until it made contact with the ground.

Nest Searches and Monitoring

Nest searches and monitoring took place from 26 May to 27 July in 2004 and from 17 May to 8 August in 2005. Nests were found using systematic rope drag searches and by incidental flushing of adult birds during other field operations (such as checking on known nests and taking vegetation measurements). Each site was searched three times during the breeding season, two to three weeks apart (Winter et al. 2003; Lloyd and Martin 2005). Enough of each site was searched to create equal sampling areas for each site type. Thus, in smaller patches, the entire patch may have been searched, while in larger patches, a reduced area was searched. In order to control for potential edge effects, searches were not conducted within 50 m of wetlands or patch borders.

Rope dragging consisted of two researchers walking parallel to each other, dragging a 30-m long nylon rope between them, while at least one searcher followed behind the rope to look for bird movement or other signs of nesting activity (Koford 1999; Winter et al 2003). When a bird was flushed, searchers stopped and looked for the nest within a 1 m^2 area of where the bird had flushed (Winter et al 2003). The nesting species was identified from the appearance of the flushed bird, eggs, or the nestlings (Koford 1999). All nests of all species found were recorded and monitored.

Each nest was marked with a flag placed 5 m north of the nest. Because cattle frequently dislodged the marking flag, I also marked the ground one meter to the north of the nest with bright marking paint. While marking nests in this way may or may not affect nest success, the marking itself was not likely to bias comparisons of nest success because all nests were marked in a consistent manner (Lloyd and Martin 2005).

The date, time and GPS coordinates of each nest were recorded on a data sheet, and each nest was given a unique identification number. Species, number of eggs, and developmental stage of any nestlings were recorded for each nest. Developmental stage was estimated based on size and feather development of nestlings (Baicich and Harrison 1978). Cowbird eggs and young were also noted. The degree of nest concealment was estimated on an objective scale of 0 through 5 to describe the percent of the nest that could be seen from directly above the nest and from the side, 1 m away, at nest height: 0 = 5% or less can be seen; 1 = 6 to 20 %; 2 = 21 to 40%; 3 = 41 to 60%; 4 = 61 to 80% and 5 = 81 to 100% (the entire nest is visible).

Researchers returned to each nest every 3 or 4 days until the nesting attempt ended. Date, time, number of eggs or young, and developmental stage of young were recorded at each visit. Nests were assumed successful if at least one chick of the host species fledged (or hatched, in the case of precocial species). Fledging was assumed if no signs of predation were present (Klett et al. 1986; Davis 2006) and the young were old enough at last visit to have fledged.

Precautions were taken to disturb nests as little as possible during both searching and monitoring (Winter et al. 2003). Nest searches were not conducted during cold or wet weather. Before approaching a known nest location, researchers scanned the surrounding area for possible predators or cowbirds. Researchers never stayed at a nest site for more than 10 minutes at a time (Winter et al. 2003). Nests were approached from different directions to avoid creating any well-worn paths (Winter et al. 2003). Researchers also attempted to stay at least 1 meter away from the nest while inspecting nest contents, and were careful not to trample the vegetation around nests (Winter et al. 2003).

Vegetation Measurements at Nest Locations

Within 1 week of the end of each nesting attempt, vegetation at the nest and 1 m north of the nest was assessed. Visual obstruction was measured at the nest bowl and also 1 meter north of the nest by taking Robel pole readings in each of the four cardinal directions (Robel et al. 1970). Measurements in each direction were averaged together to produce one number for the nest bowl and one number for the reading taken one meter north of the nest. Other measurements taken at the nest bowl and one meter north included grass height, forb height, woody vegetation height, and litter depth. A 20cm x 50cm Daubenmire frame (Daubenmire 1959) was placed over the nest bowl to estimate percent cover in live grass, forbs, litter, bare ground, and woody vegetation.

Data Analyses

Site Vegetation Structure

I calculated mean visual obstruction (Robel), mean grass, forb and woody vegetation heights, and litter depth from vegetation surveys done along bird survey transects in each field and used analysis of variance (ANOVA) to evaluate whether structure differed between site types. Post-hoc tests (Bonferroni) were used to evaluate the influence of site type on these estimates. All statistical tests were considered significant at $p \leq 0.05$.

Species Density

I calculated mean density for each species from bird surveys for each field and used analysis of variance (ANOVA) to evaluate whether density differed between site types. Post-hoc tests (Bonferroni) were used to evaluate the influence of site type on these estimates.

Nest Survival

The nest survival model in program MARK (White and Burnham 1999; Rotella 2004) was used to determine nest survival probabilities as a function of vegetation, patch and landscape variables (Table 3). Akaike's Information Criterion corrected for small size (AICc) (Akaike 1969; Burnham and Anderson 2002) was used for model selection. I considered the model that yielded the smallest AICc value the best approximation for the information in the data set (Burnham & Anderson 2002). Included in the first set of competing models were all single vegetation variables considered to be biologically significant to the species or group being analyzed, single variables of patch and landscape, and the constant daily survival rate. Individual species analyzed included chestnut-collared longspurs, western meadowlarks, and ring-necked pheasants. Savannah and grasshopper sparrow nests were combined for purposes of analysis. All duck species were analyzed as one group. For chestnut-collared longspurs, meadowlarks, savannah sparrows and grasshopper sparrows, these models included Robel, grass height, forb height, litter depth, cowbird (parasitized or not), patch size and landscape (< 40% or >50% grass in surrounding landscape). For dabbling ducks and ring-necked pheasants, single models included Robel, grass height, forb height, litter depth, patch size, and landscape.

Combinations of the best resulting models were added to evaluate whether combined variables were having a greater effect on survival than individual variables. Nest parasitism was included in models for species that were parasitized by cowbirds. Each nest was considered a sampling unit. Since I did not use the same sites each year, year was not included in analysis. I used 17 May as Day 1 of the nesting season for both combined years.

Parasitism

I used forward stepwise logistic regression (Hosmer and Lemeshow 1989) to construct models to evaluate the influence of vegetation, patch and landscape variables on the likelihood of nest parasitism for chestnut-collared longspurs, grasshopper and savannah sparrows, and western meadowlarks. In the first candidate model for each species, only uncorrelated vegetation variables were allowed to enter into equations. In a second set of candidate models, vegetation, patch and landscape variables were allowed to enter the equation. Threshold p values for entering and removing model variables were 0.15 and 0.05, respectively. I used Akaike's Information Criterion adjusted for small sample size (AICc; Akaike 1969; Liberton et al. 1992; Burnham and Anderson 2002) as a basis for model selection. I considered the model that yielded the smallest AICc value the best approximation for the information in the data set (Burnham and Anderson 2002).

CHAPTER 3 – RESULTS

Site Vegetation Structure

There were no significant differences ($p>0.05$) in any vegetation measurement between site types (Table 4). This indicated that site selection ensured similar vegetation structure between site types.

Avian Surveys

A total of 11 passerine species were detected during the surveys (Table 5). Chestnut-collared longspurs were present on both large patch site types, on two small patch/high-percentage landscape grass sites, but not on any small patch with low percentage of grass in the surrounding landscape. Grasshopper sparrows were detected on 100% of the large patches, but only 67% and 44% of the smaller patches. Savannah sparrows were detected on 100% of large patches within high grass landscapes, 50% of large patches within low grass landscapes, 67% of small patches within high grass landscapes, and 67% of small patches within low grass landscapes. Western meadowlarks were present at all sites. Bobolinks were present at 33% of small/low grass sites, at 20% of small/high grass sites, at 50% of large/low grass sites, and not present at large/high grass sites. Baird's sparrows (*Ammodramus bairdii*) were not detected in surveys but were present at two sites (a large patch surrounded by < 40 % grass and a large patch surrounded by >50 %grass).

50% of large/low grass sites during a walkabout.

Density of chestnut-collared longspurs was significantly higher ($p<0.01$) in large patch/low-percentage grassland landscape sites (Table 6). Density of grasshopper sparrows was significantly higher ($p<0.01$) on large versus small patches, regardless of landscape composition (Table 6). Density of savannah sparrows, western meadowlarks, red-winged blackbirds, brown-headed cowbirds and eastern kingbirds did not differ significantly ($p > 0.05$) between site types.

Nest Survival

A total of 210 nests with known fates were found during both years (Table 7). I did not analyze non-grassland obligates. Upland sandpiper (n=11) and sharp-tailed grouse (n=2) nests were not analyzed due to low sample size. Savannah sparrow nests (n=7) were combined with grasshopper sparrow nests (n=18) for purposes of model analysis. Morning dove nests (n=7) and red-winged blackbird nests (n=6) were not included in the analysis because they are not grassland obligates. After all exclusions, a total of 178 nests were used in my analysis.

Upland Sandpiper

Upland sandpiper nests were located in all landscape types. A total of 13 nests was found, of which 69% hatched (Table 7). One nest contained a brown-headed cowbird egg (Figure 2). Five of the 8 successful nests hatched between 6 June and 17 June. The latest hatch date was 8 July. Mean clutch size was 3.83 with mean of 2.54 hatched (Table 8).

Chestnut-collared Longspurs

The two peak hatch dates for chestnut-collared longspur nests were June 22-25 and July 23-27. The latest successful nest fledged on 11 August. Mean clutch size was 3.42 and mean number fledged was 1.80 (Table 8). Three nests were parasitized of which two successfully fledged chestnut-collared longspur young. Chestnut-collared longspur nests had a constant daily survival rate (DSR) of 0.954 (95% CI = 0.928-0.970), giving a Mayfield (1975) nest success estimate of 0.29 (Table 7). No model had a lower AICc than the DSR alone, indicating that no model explained more variation in nesting success (Table 9). Litter depth was the closest model to the DSR, indicating that litter depth had the most influence on nest success. There was some support for the effects of patch size on nest success (AICc < 2), with DSR being higher in large patches. When combined with litter depth, landscape also showed a positive effect. No vegetation, patch or landscape variable entered into the models evaluating likelihood of parasitism of chestnut-collared longspur nests, likely due to low parasitism rates (Figure 2).

Western Meadowlarks

Fledging dates for the 18 successful western meadowlark nests ranged from 3 June to 11 August. Mean clutch size was 3.58, and mean number fledged was 1.40 (Table 8). Constant daily survival rate for western meadowlark nests was 0.954 (95%CI = 0.928-0.970), giving a Mayfield (1975) nest success estimate of 0.24 (Table 6). Grass height + forb height was the best model (Table 10). However, 6 different models were within 2 AICc units. Grass height was included in all of these. Forb height and Robel were also present in the four of the best models. Patch and landscape, in combination with vegetation variables, were present in 2 of the best models. Daily nest survival was 0.967 in small patches compared to 0.926 in large patches. The highest success rates were in small patches surrounded by grass. Landscape was included in models within 2 AIC units, it was positively related to nest survival: DSR in low-percentage grass landscapes was 0.950 compared to 0.958 in high-percentage grass landscapes. Sixteen out of 36 western meadowlark nests, or 44%, were parasitized (Figure 2). Cowbird parasitism, however, did not appear in any of the top-ranking models, indicating that parasitism did not explain additional variation in nest survival. No vegetation, patch or landscape variable entered into the logistic models evaluating likelihood of parasitism of western meadowlark nests.

Savannah Sparrows and Grasshopper Sparrows

A total of 18 grasshopper sparrow nests and 7 savannah sparrow nests were located during 2 years of nest searching (Table 6). Fledging dates for grasshopper sparrows ranged from 18 June to 28 July. Mean clutch size was 3.38. Mean number fledged was 1.83 (Table 8). For savannah sparrows, fledge dates ranged from 15 June to 25 July. Mean clutch size was 2.57 and mean number fledged was 1.86 (Table 8). Constant daily survival for savannah and grasshopper sparrow nests combined was 0.933 (95% CI = 0.891-0.959). Mayfield (1975) nest success was 0.18. Landscape was the most important variable affecting daily nest survival (Table 11). Daily nest survival in high grass (>50%) landscapes was 0.969, while in low grass (<40%) landscapes survival was 0.908. Landscape combined with local vegetation variables (Robel and forb height), patch and cowbird parasitism all showed ΔAICc <2, indicating they are important variables affecting daily nest survival. Six out of 18 grasshopper sparrow nests were parasitized (33%), while 3 out of 7 savannah sparrow nests were parasitized (43%) (Figure 2). Patch area was the best model of the likelihood of nest parasitism by the brown-headed cowbird. The likelihood of nest parasitism for grasshopper and savannah sparrows decreased significantly with increasing patch size (Figure 5).

Dabbling Ducks

A total of 38 dabbling duck nests were found in both years, including 26 mallard, 5 gadwall, 6 blue-winged teal, and 1 northern shoveler (*Anas clypeata*) (Table 6). Hatch dates of successful duck nests ranged from 15 June to 4 August. Mean clutch size was 8.31. Mean number hatched was 2.48 (Table 8). Dabbling duck nests showed a constant daily survival of 0.959 (95%CI = 0.937-0.973), with a Mayfield (1975) estimate of 0.21 (Table 6). Grass height was included in all three models that explained more variation than DSR alone (Table 10). Daily nest survivorship increased with increasing grass height (Figure 6). The combination of grass height with patch and landscape also formed a competing model. Patch was positively correlated with nest survival and landscape was negatively correlated. Daily survivorship increased in larger patches (0.941 in small patches vs. 0.966 in large patches). Daily survivorship in low grass landscapes was 0.963 compared to 0.917 in high grass landscapes.

Ring-necked Pheasants

A total of 29 ring-necked pheasant nests were found during this study, 1 of which was excluded from analysis due to uncertain nest fate. The 6 successful nests hatched from 2 June to 8 July. Mean clutch size was 11.11 (SE±0.69). Mean number hatched was 2.10 (SE±3.86) (Table 8). The DSR for ring-necked pheasant nests was 0.936 (95%CI = 0.905-0.958), with a Mayfield (1975) estimate of 0.10 (Table 6). Robel was the best model affecting daily nest survival (Table 11). Nest survival increased with increasing Robel measurements (Figure 7). The Robel + patch and Robel + landscape models were below DSR, but still within 2 ΔAICc of the best model. Daily nest survival was negatively correlated with both patch size and landscape.

CHAPTER 4-DISCUSSION

Chestnut-collared Longspur

Chestnut-collared longspurs presence, density and daily nest survival were higher in large versus small patches, regardless of surrounding landscape context. Almost all of the chestnut-collared longspur nests were found in large patches, despite the birds' presence in smaller patches. Few studies have been done on the influence of patch size on chestnut-collared longspur nest success. Davis et al. (2006), found a negative correlation to patch size in for nest success of chestnut-collared longspurs in southern Saskatchewan, but the correlation was weak. This weakness may be due to the fact that landscape was not explicitly considered in that study; small patches were all in low-percentage grass landscapes, and large patches were all in high-percentage grass landscapes (Davis et al. 2006).

Litter depth was the only vegetation variable to enter into any of the more likely models to explain variation in nest success. Most chestnut-collared longspur nests in my study were located in areas without much litter, but daily nest survival for chestnut-collared longspurs increased with increasing litter depth. One possible explanation for this is that litter attracts insects, which provide important sources of protein for incubating adults and growing chicks (Jensen, K.C., personal communication). Having an increased source of insects close to the nest may thus increase survival.

My results indicate that parasitism on chestnut-collared longspurs is minimal in north central South Dakota pastures. Davis (1994) also found low parasitism rates (14%) for chestnut-collared longspurs nesting in southwest Manitoba. This may be because the relatively exposed structure of longspur nests makes it difficult for cowbirds to lay their eggs without being detected (Davis 1994).

Davis et al. (2006) attributed a much stronger correlation between nest success and time-specific effects (i.e., nest age and date) than between nest success and vegetation, patch or landscape variables. Lloyd and Martin (2005) also noted a time-specific effect independent of habitat, as nest survival in chestnut-collared longspurs nesting in eastern Montana generally declined throughout the nesting cycle. Lloyd and Martin's (2005) study only included first nesting attempts, while Davis et al.'s (2006) study did not specify. In this study, I did not differentiate between first and second nesting attempts. This might have reduced my overall nesting success for this species, as chestnut-collared longspurs are double brooders (Hill and Gould 1997) and the success of the second nesting attempt may decline.

Western Meadowlark

Western Meadowlark daily nest survival rates were influenced by vegetation, patch and landscape variables. These patterns indicate that a combination of local vegetation, patch and landscape all have an impact on nest survival of western meadowlarks. Similarly, Bakker et al. (2002) found local vegetation variables related to the occurrence of western meadowlarks in eastern South Dakota more than patch or landscape variables, however density was positively associated with patch size. Other studies have detected weak or no effect of patch size on occurrence or abundance (Knick and Rotenberry 1995; Johnson and Igl 2001). Renfrew (2002) found only weak associations with vegetation, patch and landscape variables in her models for meadowlark nest survival and predation in southwestern Wisconsin pastures.

Patch was negatively correlated with daily nest survival in western meadowlarks in my study. Success rates were highest in small patches, regardless of surrounding landscape composition. Davis et al. (2006) also found western meadowlark nesting success to be inversely related to patch size in southern Saskatchewan, but, like the chestnut-collared longspurs in their study, this relationship was weak, and time-specific effects (e.g., age and date) showed more influence.

Grasshopper and Savannah Sparrows

Nest survival for grasshopper and savannah sparrow nests was higher in landscapes with >50% grassland than in low grass landscapes. This is the first study to find a relationship between nest survival and the percentage of grass in the landscape for these species. Winter et al. (2006) found no correlation between landscape composition and nest success of savannah sparrows in northern tallgrass prairie of Minnesota and North Dakota. While many studies have detected an effect of patch size on occurrence and abundance of savannah and grasshopper sparrows (Herkert 1994; Vickery et al 1994; DeJong 2001; Bakker et al 2002), the importance of patch and landscape factors on occurrence and density has been shown to vary across regions, especially between tallgrass, mixed grass and shortgrass prairies (Bakker et al. 2002; Skagen et al. 2005). While patch size has not been shown to directly affect nesting success for these (Winter and Faaborg 1999; Davis 2006), Herkert et al. (2003) did find that predation rates were consistently lower for grasshopper sparrows on larger size (>100 ha) grasslands across a 5 state region in the Midwest and Great Plains .

The probability of cowbird parasitism of grasshopper and savannah sparrow nests decreased with increasing patch size in my study. Other studies have also found a negative correlation between patch size and likelihood of cowbird parasitism (Johnson and Temple 1990; Johnson and Igl 2001; Patten et al. 2006). This correlation may be due to closer proximity of fencerow edges and roadside vegetation (habitat edge) in smaller patches, which provide perches from which cowbirds can search the nesting area for possible hosts (Shaffer et al. 2003; Patten et al. 2006), and also due to the increased difficulty of finding nests in larger patches. Herkert et al. (2003) found that cowbird parasitism rates on 5 grassland passerines varied across regions but not within different sized patches in Illinois, Missouri, Kansas, North Dakota and Oklahoma. They concluded that parasitism rates were not affected by patch size as much as by the regional abundance of cowbirds. My study was conducted within a small geographic area where cowbird abundance is high (Sauer et al. 2005). On a regional scale, patch size may not be as important as regional abundance of cowbirds, but on a more local study such as this, patch size had a strong influence on the likelihood of parasitism.

Dabbling Ducks

Dabbling duck nest survival was influenced by vegetation, patch size and landscape. Nest survival increased in larger patches, regardless of the surrounding landscape. This is similar to findings of other studies (Ball et al. 1995; Sovada et al. 2000). Horn et al. (2005) found nest success of ducks in central North Dakota to be highest in both large and small patches, and lowest in intermediate-sized patches, possibly due to differences in predator activity levels in different sized fields.

Nest survival in this study decreased in landscapes with >50% grassland habitat surrounding the patch as compared to those with <40%. The negative correlation between landscape and nest success contrasts with other studies which found increased duck nest success in high grass landscapes (Phillips et al. 2003; Horn et al. 2005; Stephens et al. 2005). Horn et al. (2005) found nest success of ducks in high grass (45-55%) landscapes to be higher than nest success in low grass (15-20%) landscapes. In that study, the difference between high and low grass landscapes affected edge effects, where edge effects were stronger in high grass landscapes. In my study, raw nest success was lowest in small patches surrounded by grass. Since duck nest success was lower in small patches in my study, perhaps high-grass landscape actually increased the detrimental effects of increased predation rates found in other studies (Ball et al. 1995; Sovada et al. 2000), thus showing up as a negative correlation to nest success. It is also possible that using 4 types of landscapes is confounding my results. The positive correlation between patch size shows up as a negative relationship between landscape types. The positive relationship between patch size and nest survival was stronger than the negative correlation between landscape (% grass) and nest survival.

Ring-necked Pheasant

Visual obstruction at the nest bowl (Robel) was the best model for daily nest survival of ring-necked pheasants. In general, vegetation structure is an important consideration for increasing pheasant productivity (Trautman 1982). Recent studies have compared nesting structure in CRP fields planted with warm-season versus cool-season grasses (Rock 2006) and in older vs. younger plantings (Eggebo et al. 2003), but little research has been conducted on pheasants nesting in native pastures.

Nest survival of ring-necked pheasants was also influenced by patch size and landscape composition. Pheasant daily nest survival was lower in high grass landscapes and in large patches. Conversely, Clark et al. (1999) found a positive relationship between nest success and patch size for ring-necked pheasants in Iowa. This discrepancy in results could be due to the added effect of landscape and differences in patch size categorization and fragmentation of study areas. Clark et al.'s (1999) study took place in a highly fragmented area and their large patches (≥ 15 ha) are much smaller than patches classified as large (>100 ha) in this study, which took place in a less fragmented area.

Patch Size and Landscape

Clearly, species and groups varied in their responses to vegetation, patch and landscape variables. For all but one of my bird groups, vegetation characteristics, either singly or in combination, were included in the best models for predicting nest success. This is consistent with other studies that have found local variables (vegetation characteristics) to be more important than patch or landscape variables in determining nest success (Koper and Schmiegelow 2006; Winter et al. 2006). Winter et al. (2006) found patch and landscape variables had no clear effect on nesting success of clay-colored sparrows, savannah sparrows, or bobolinks in three regions of northern tallgrass prairie. Davis et al. (2006) found patch size to have variable influence on nesting success in mixed grass prairie of southern Saskatchewan: Sprague's pipit (*Anthus spragueii*) and clay-colored sparrows showed no response to patch size; savannah sparrow nest success increased with increased patch size; and Baird's sparrows, chestnut-collared longspur and western meadowlark nest success actually decreased with increasing patch size.

In my study, patch size was positively correlated with nest success of chestnut-collared longspurs and waterfowl, while savannah and grasshopper sparrow nests were less likely to be parasitized in large patches. Patch size was negatively correlated with the nest success of western meadowlarks and ring-necked pheasants.

This study showed a positive correlation between high-percentage (>50%) grass landscapes and nesting success of savannah sparrows, grasshopper sparrows, and western meadowlarks. Duck nest success, however, was negatively correlated with landscape. Other studies detected higher nest success for ducks in high grass landscapes (Philips et al. 2003; Horn et al. 2005; Stephens et al. 2005). Several studies detected no landscape effect on nesting success of passerines or ducks (Howard et al. 2001; Koper and Schmiegelow 2006; Winter et al. 2006).

The design of a study, including sample size and landscape scale, may influence whether a landscape effect is detected. Larger sample sizes, longer studies and landscape analysis at large multiple spatial scales may improve the chance of detecting a landscape effect (Stephens et al. 2003; Winter et al. 2006). Similarly the degree of fragmentation o of the study area could lead to differences in detection of landscape effects. Stephens et al. (2003) also highlighted the importance of landscape in relation to predator dynamics as a way of explaining variations in nest success, as predators have been shown to respond to fragmentation more at landscape levels than at local scales (Chalfoun et al. 2002).

CHAPTER 5-CONLUSIONS AND MANAGEMENT IMPLICATIONS

Effects of landscape and patch size on nesting success are quite variable, differing between species, geographical areas, years, and study methods. I detected patch and landscape attribute effects on daily nest survival rates for chestnut-collared longspurs, western meadowlarks, savannah and grasshopper sparrows, and dabbling ducks in native sod pastures of north central South Dakota.

Local vegetation, patch and landscape variables are all important factors in understanding the habitat needs of grassland nesting birds. In my study, vegetation variables were important for nest survival of chestnut-collared longspurs, western meadowlarks, waterfowl, and ring-necked pheasants. Landscape (high or low percentage grass in the surrounding landscape) was included in the best models for savannah and grasshopper sparrows and western meadowlarks. Patch size, in combination with vegetation variables, was important for waterfowl, chestnut-collared longspurs, and western meadowlarks. Patch size also affected the parasitism rate on savannah and grasshopper sparrow nests.

With these things in mind, research and management recommendations are as follows:

(1) Continue research addressing the effects of fragmentation on nest success, incorporating multiple landscape scales and an emphasis on longer running studies.

(2) Incorporate predator activity into these studies to add valuable knowledge on how predators behave in different landscapes.

(3) Preserve large tracts of uninterrupted native prairie. Larger patches were shown to increase daily survival of chestnut-collared longspur and dabbling duck nests. Parasitism rates of savannah and grasshopper nests also decreased in large patches as compared to small.

(4) Preserve smaller prairie patches, especially those embedded in high grass landscapes with abundant grassland. Nest survival rates for western meadowlarks to be highest in small patches surrounded by high percentage grassland habitat. High grass landscapes also improved daily nest survival rate for savannah and grasshopper sparrows.

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Table 1. Four site types on which the nesting study was conducted in north central South Dakota, 2004-2005. Categories reflect differences in patch size and landscape composition in north central South Dakota, 2004-2005.

Site Type	1	2	3	4
Patch Size	< 50 ha	< 50 ha	> 100 ha	> 100 ha
% Grass in Surrounding Landscape	< 40%	> 50%	< 40%	> 50%

Table 2. Location of, total area of and area searched for nests in study sites located in north central South Dakota searched 2004-2005.

Type	Site	County	S-T-R (Section-Township-Range)	Area Total (ha)	Area Searched (ha)
Small/Low Grass (Type 1)	Scheutzel	Campbell	31-127-77	23	23
	Maslon 2	Edmunds	12-123-68	32	32
	Davis North	Edmunds	09-124-68	24	24
	Davis 4	Edmunds	07-124-68	24	24
	Kessler	McPherson	18-25-67	14	14
	Steven	Edmunds	04-123-68	49	40
	TOTAL			**166**	**157**
Small/High Grass (Type 2)	Ohio Trucker	Campbell	34-127-74	6	6
	Bieber	McPherson	27-126-68	12	8
	Biel	McPherson	27-125-75	29	29
	GFP	McPherson	10-126-73	21	21
	Weller	Edmunds	6-126-73	6	6
	Ordway House	McPherson	23-126-69	28	28
	Davis 3	Edmunds	07-124-68	12	12
	Ordenbach	McPherson	14-128-73	12	12
	Kirschmann	Edmunds	06-122-69	40	30
	TOTAL			**166**	**152**
Large/Low Grass (Type 3)	Feinstein	McPherson	31-126-73	173	101
	Beyer	Edmunds	31-123-69	80	60
	TOTAL			**153**	**161**
Large/High Grass (Type 4)	Ordway 2	McPherson	19-126-68	161	121
	Ordway	McPherson	20-126-68	58	32
	TOTAL			**219**	**153**

Table 3. Independent variables used in analysis of nest survival of grassland birds in north central South Dakota, 2004-2005.

Variable	**Explanation**	**Units**	**Variable Type**
Age	Age of nest in days	Number	Continuous
CB	Cowbird parasitism	0 or 1*	Categorical
Hectares	Area of patch	Number	Continuous
Patch	<50 HA or >100 HA	0 or 1	Categorical
Landscape	< 40% grass or > 50% grass	0 or 1	Categorical
NCAB	Nest concealment from above	0 to 5	Continuous
NCSID	Nest concealment from side	0 to 5	Continuous
Robel 1	Visual obscurement at nest	Number (dm)	Continuous
GH	Grass height	Number (dm)	Continuous
FH	Forb height	Number (dm)	Continuous
WV	Woody Vegetation height	Number (dm)	Continuous
LD	Litter depth	Number (mm)	Continuous
DALiv	Daubenmire Live	Percentage	Continuous
DAFor	Daubenmire Forb	Percentage	Continuous
DALit	Daubenmire litter	Percentage	Continuous
DABar	Daubenmire bare ground	Percentage	Continuous
Wood	# woody stems in frame	Number	Continuous
Robel 2	Visual obscurement 4 m from nest	Number (dm)	Continuous

*0=parasitized; 1=not parasitized

Table 4. Mean (± SE) vegetation measurements by site type in native pastures (n=19) in north central South Dakota, 2004-2005.

Measurement	**Type 1**	**Type 2**	**Type 3**	**Type 4**
Robel (dm)	1.7 (0.3)	2.0 (0.3)	1.0 (0.3)	1.2 (0.1)
Grass Height (dm)	6.2 (0.7)	7.3 (0.5)	5.3 (0.7)	7.7 (1.3)
Forb Height (dm)	5.5 (0.4)	5.1 (0.05)	3.1 (0.6)	3.6 (0.7)
Woody Height (dm)	0.5 (0.5)	0.2 (0.2)	0.0 (0.0)	0.0 (0.0)
Litter Depth (mm)	7.0 (3.0)	12.0 (6.0)	11.0 (5.0)	5.5 (5.0)

Table 5. Passerine presence by site type in native pastures (n=19) in north central South Dakota, 2004-2005.

Species	**Type 1 (n=6)**	**Type 2 (n=9)**	**Type 3 (n=2)**	**Type 4 (n=2)**
Red-winged blackbird (*Agelaius phoeniceus*)	83%	89%	50%	50%
Bobolink (*Dolichonyx oryzivorus*)	67%	56%	50%	0%
Grasshopper sparrow (*Ammodramus savannarum*)	67%	44%	100%	100%
Western meadowlark (*Sturnella neglecta*)	100%	100%	100%	100%
Brown-headed cowbird (*Molothrus ater*)	83%	56%	50%	100%
Savannah sparrow (*Passerculus sandwichensis*)	67%	67%	50%	100%
Eastern kingbird (*Tyrannus tyrannus*)	67%	56%	50%	0%
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*)	17%	0%	0%	0%
Horned lark (*Eremophila alpestris*)	17%	0%	0%	0%
Chestnut-collared longspur (*Calcarius ornatus*)	0%	22%	50%	50%

Table 6. Passerine density (birds per 100 ha) by site type in native pastures (n=19) in northeastern South Dakota, 2004-2005. Standard errors are in parentheses. Superscripts with different letters indicate densities that are significantly different ($p<0.05$) from other values within the row.

Species	**Type 1 (n=6)**	**Type 2 (n=9)**	**Type 3 (n=2)**	**Type 4 (n=2)**
Red-winged blackbird (*Agelaius phoeniceus*)	42.5 (16.3)	41.7 (12.5)	37.5 (37.5)	12.5 (12.5)
Bobolink (*Dolichonyx oryzivorus*)	33.3 (15.7)	19.4 (8.1)	25.0 (25.0)	0
Grasshopper sparrow (*Ammodramus savannarum*)	33.3[a] (12.4)	16.7 (7.2)[a]	75 (0)[b]	87.5 (12.5)[b]
Western meadowlark (*Sturnella neglecta*)	50.0 (9.1)	44.4 (10.0)	50.0 (25.0)	100.0 (50.0)
Brown-headed cowbird (*Molothrus ater*)	29.2 (10.0)	33.3 (13.8)	25.0 (25.0)	50.0 (0)
Savannah sparrow (*Passerculus sandwichensis*)	20.8 (10.0)	30.6 (12.3)	12.5 (12.5)	62.5 (37.5)
Eastern kingbird (*Tyrannus tyrannus*)	29.2 (15.0)	11.1 (4.4)	25.0 (25.0)	12.5 (12.5)
Horned lark (*Eremophila alpestris*)	8.3 (8.3)	0	0	0
Chestnut-collared longspur (*Calcarius ornatus*)	0[a]	5.6 (3.7)[a]	100 (50)[b]	12.5 (12.5[a])

Table 7. Total number of nests located, nests used in analysis, nest success and daily survival rates by species for nests found in native pastures (n=19) in north central South Dakota, 2004-2005.

Species	***Total Nests Found**	**Nests Used in Analysis**	**Raw Nest Success**	****Mayfield Nest Success**	****Daily Survival Rate**
Chestnut-collared Longspur (*Calacarius ornatus*)	57	42	55%	.29	.954
Western Meadowlark (*Sturnella neglecta*)	32	32	53%	.24	.954
Grasshopper Sparrow (*Ammodramus savannarum*)	18	17	44%	.12	.918
Savannah Sparrow (*Passerculus sandwichensis*)	7	7	43%	.37	.964
Upland Sandpiper (*Bartamia longicauda*)	13	NA	69%	NA	NA
Dabbling Ducks (*Anas spp.*)	38	37	46%	.21	.959
Blue-winged Teal (*Anas discors*)	6	6	50%	.24	.962
Gadwall (*Anas strepera*)	5	4	75%	.32	.970
Mallard (*Anas platyrhynchos*)	26	26	42%	.31	.956
Northern Shoveler (*Anas clypeata*)	1	1	0%	0	NA
Ring-necked Pheasant (*Phasianus colchicus*)	29	28	21%	.10	.936
Mourning Dove (*Zedaida macroura*)	7	NA	67%	NA	NA
Red-winged Blackbird (*Agelaius phoeniceus*)	6	NA	50%	NA	NA
(Sharp-tailed Grouse (*Tympanuchus phasianellus*)	2	NA	100%	NA	NA
TOTAL	210	188			

*Includes nests found in all sites searched
**Includes only nests used in MARK analysis

Table 8. Hatching/fledging dates, mean clutch sizes (± SE) and mean numbers hatched/fledged (± SE) by species for nests located in native prairie pastures (n=19) in north central South Dakota, 2004-2005.

Species	**Hatch/Fledge Date Range**	**Clutch Size Mean (±SE) Min - max**	**Cowbird eggs Mean (±SE) Min - max**	**Hatched/fledged (host) Mean (±SE) Min – max**
Chestnut-collared Longspur (*Calcarius ornatus*)	19 May – 27 July	3.42 (0.17) 1 - 6	0.12 (0.06) 0 - 2	1.80 (0.25) 0 – 5
Western Meadowlark (*Sturnella neglecta*)	3 June – 11 August	3.58 (0.32) 1 - 6	1.13 (0.31) 0 - 6	1.40 (0.32) 0 – 6
Grasshopper Sparrow (*Ammodramus savannarum*)	18 June – 28 July	3.38 (0.45) 1 - 5	0.89 (0.40) 0 - 6	1.83 (0.52) 0 – 5
Savannah Sparrow (*Passerculus sandwichensis*)	15 June – 25 July	2.57 (0.65) 1 - 5	0.86 (0.50) 0 - 3	1.86 (0.80) 0 – 5
Upland Sandpiper (*Bartamia longicauda*)	6 June – 17 June	3.83 (0.11) 3 - 4	0.08 (0.08) 0 - 1	2.54 (0.50) 0 – 4
Dabbling Ducks (*Anas spp*.)	15 June – 4 August	8.31 (0.30) 5 - 11	NA	2.48 (3.66) 0 – 11
Ring-necked Pheasant (*Phasianus colchicus*)	2 June – 8 July	11.11 (0.69) 3 – 19	NA	2.10 (3.86) 0 – 10

Table 9. Best explanatory models for daily survival rate (DSR) of chestnut-collared longspur nests in north central South Dakota pastures, 2004 and 2005. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 3 for explanations of variables.

Models	**AICc**	**ΔAICc**	**AIC weights**	**No. of parameters**
Daily survival rate (DSR)	97.118	0	0.1574	1
LD	97.2934	0.1754	0.14418	2
LD+landscape	98.9095	1.7915	0.06427	3
Patch	98.923	1.805	0.06383	2
LD+patch	98.9441	1.8261	0.06316	3
LD+Robel	99.2612	2.1423	0.0539	3
LD+patch+landscape	99.6698	2.5518	0.04394	4
CB+landscape	100.3285	3.2105	0.2008	3
CB+LD+landscape	100.342	3.224	0.0314	4
Patch+Robel	100.3606	3.2426	0.03111	3
CB+LD+patch	100.4602	3.3422	0.0296	4
Patch+landscape	100.82	3.702	0.02472	3
LD+Robel+patch	100.9428	3.8248	0.02325	4
Robel	101.1224	4.0044	0.02125	2
Patch	101.7585	4.6405	0.01546	2
GH	104.1793	7.0613	0.00461	2
FH	105.2019	8.0839	0.00276	2
Landscape	105.9546	8.8366	0.0019	2

Table 10. Best explanatory models for daily survival rate (DSR) of western meadowlark nests in north central South Dakota pastures, 2004 and 2005. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 3 for explanations of variables.

Models	**AICc**	**Δ AICc**	**AICc weights**	**No. of parameters**
GH+FH	93.6201	0	0.15575	3
GH	94.4015	0.7814	0.10538	2
GH+Robel	94.5023	0.8822	0.1002	3
Patch+GH+Robel	94.5116	0.8915	0.09973	4
GH+landscape+FH	95.229	1.6089	0.06967	4
GH+landscape	95.2677	1.6476	0.06834	3
GH+FH+patch	95.5238	1.9037	0.06012	4
Patch+GH	96.0016	2.3815	0.04735	3
GH+CB	96.4036	2.7835	0.03872	3
Patch+Robel	96.6693	3.0492	0.03391	3
Patch+FH	97.1402	3.5201	0.02679	3
Patch	97.2262	3.6061	0.02567	2
Patch+LD	97.2725	3.6524	0.02508	3
Patch+landscape+GH	97.2814	3.6613	0.02497	4
Patch+GH+LD	97.3336	3.7135	0.02432	4
FH	97.9607	4.3406	0.01778	2
Patch+landscape+FH	98.5533	4.9332	0.01322	4
Constant DSR	98.5755	4.9554	0.01307	1
Patch+landscape	99.0456	5.4255	0.01033	3

Table 10. Continued.

Models	**AICc**	**Δ AICc**	**AICc weights**	**No. of parameters**
patch+CB	99.2547	5.6346	0.00931	3
FH+CB	99.9541	6.334	0.00656	3
Robel	100.1237	6.5036	0.00603	2
LD	100.3753	6.7552	0.00532	2
Landscape	100.4413	6.8212	0.00514	2
CB	100.5544	6.9343	0.00486	2
Robel+CB	101.9738	8.3537	0.00239	3

Table 11. Best explanatory models for daily survival rate (DSR) of grasshopper and savannah sparrow nests in north central South Dakota, 2004 and 2005. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 3 for explanations of variables.

Model	**AICc**	**Δ AICc**	**AICc weights**	**No. of parameters**
Landscape	55.7263	0	0.17479	2
landscape+Robel	56.7255	0.9992	0.10606	3
landscape+patch	57.0811	1.3548	0.08878	3
landscape+FH	57.2635	1.5372	0.08104	3
DSR	57.319	1.5927	0.07882	1
landscape+CB	57.5405	1.8142	0.07056	3
landscape+LD	57.774	2.0477	0.06278	3
landscape+FH+Robel	57.9445	2.2182	0.05765	4
patch+Robel_landscape	57.9848	2.2585	0.0565	4
FH	58.1221	2.3958	0.05276	2
CB	58.699	2.9727	0.03954	2
landscape+FH+patch	58.8268	3.1005	0.03709	4
Patch	59.1053	3.379	0.03227	2
LD	59.2493	3.523	0.03003	2
patch+FH	60.097	4.3707	0.01965	3
patch+Robel	61.1372	5.4109	0.01168	3

Table 12. Best explanatory models for daily survival rate (DSR) of dabbling duck nests in north central South Dakota pastures, 2004 and 2005. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 3 for explanations of variables.

Model	**AICc**	**Δ AICc**	**AICc weights**	**No. of Parameters**
GH+landscape	103.0815	0	0.2607	3
GH	103.2386	0.1571	0.241	2
GH+patch	104.6323	1.5508	0.12006	3
DSR	105.6371	2.5556	0.07264	1
Landscape	105.804	2.7225	0.06683	2
Patch	106.2585	3.177	0.05324	2
Landscape+patch	106.3852	3.3037	0.04997	3
Robel	106.414	3.3325	0.04926	2
FH	107.3897	4.3082	0.03024	2
Patch+Robel	107.4022	4.3207	0.03005	3
Patch+Robel+landscape	107.6916	4.6101	0.02601	4

Table 13. Evaluation of daily survival rate (DSR) models using Akaike's Information Criteria adjusted for small sample size (AICc) for ring-necked pheasants nests found in north central South Dakota pastures, 2004 and 2005. See Table 3 for explanations of variables.

Model	**AICc**	**Δ AICc**	**AICc weights**	**No. of Parameters**
Robel	109.9704	0	0.20808	2
DSR	110.2789	0.3085	0.17833	1
Robel+patch	111.1815	1.2111	0.11356	3
Robel+landscape	112.002	2.0316	0.07535	3
GH	112.1065	2.1361	0.07151	2
FH	112.2052	2.2348	0.06807	2
Patch	112.2086	2.2382	0.06795	2
Landscape	112.2739	2.3035	0.06577	2
LD	112.3036	2.3332	0.0648	2
Robel+patch+landscape	113.0995	3.1291	0.04353	4
Robel+patch+FH	113.1217	3.1513	0.04305	4

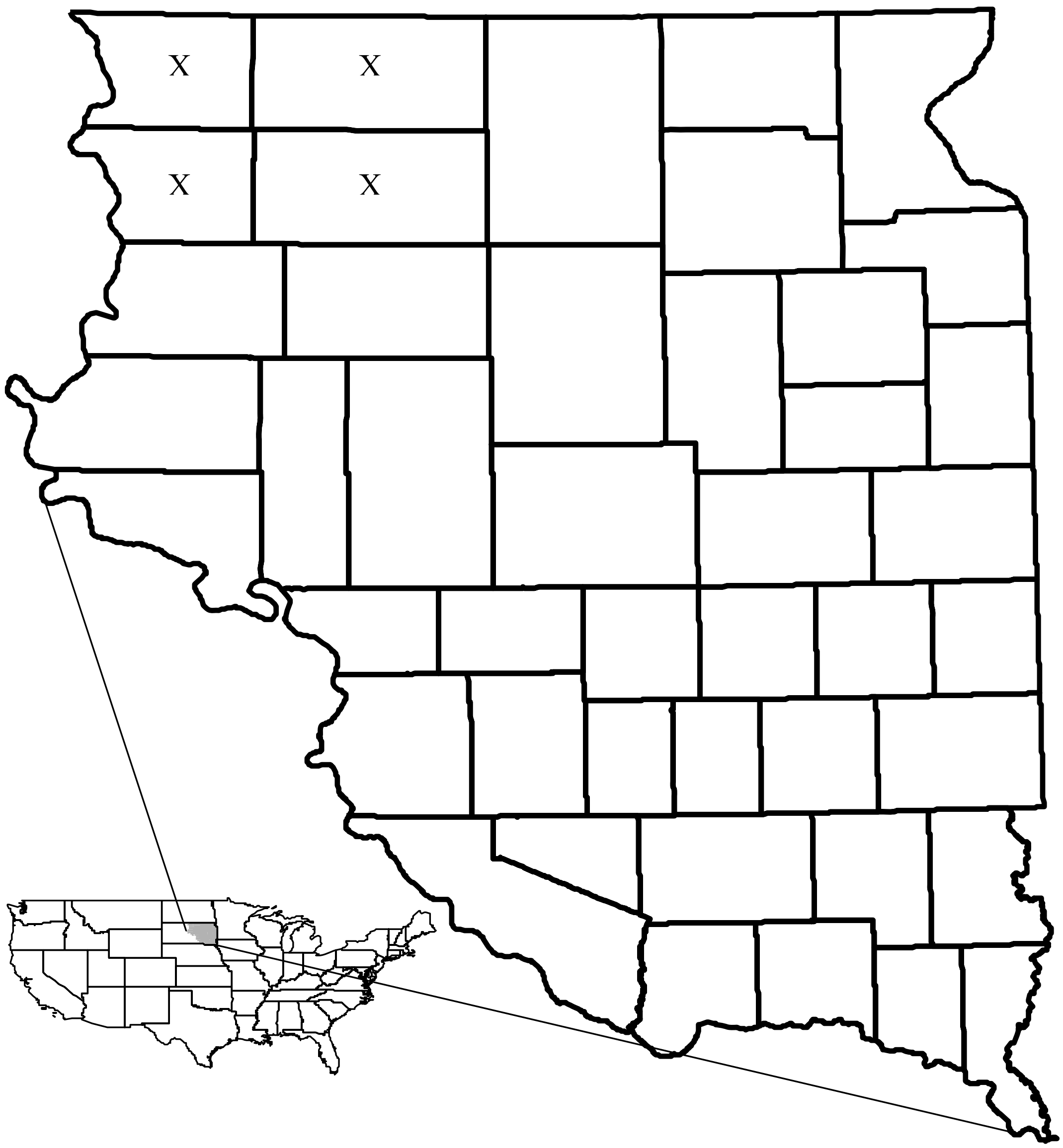

Figure 1: Map of eastern South Dakota showing study area in the north central part of the state. Counties where pastures were searched for grassland bird nests are marked by an X and include: McPherson, Campbell, Walworth and Edmunds.

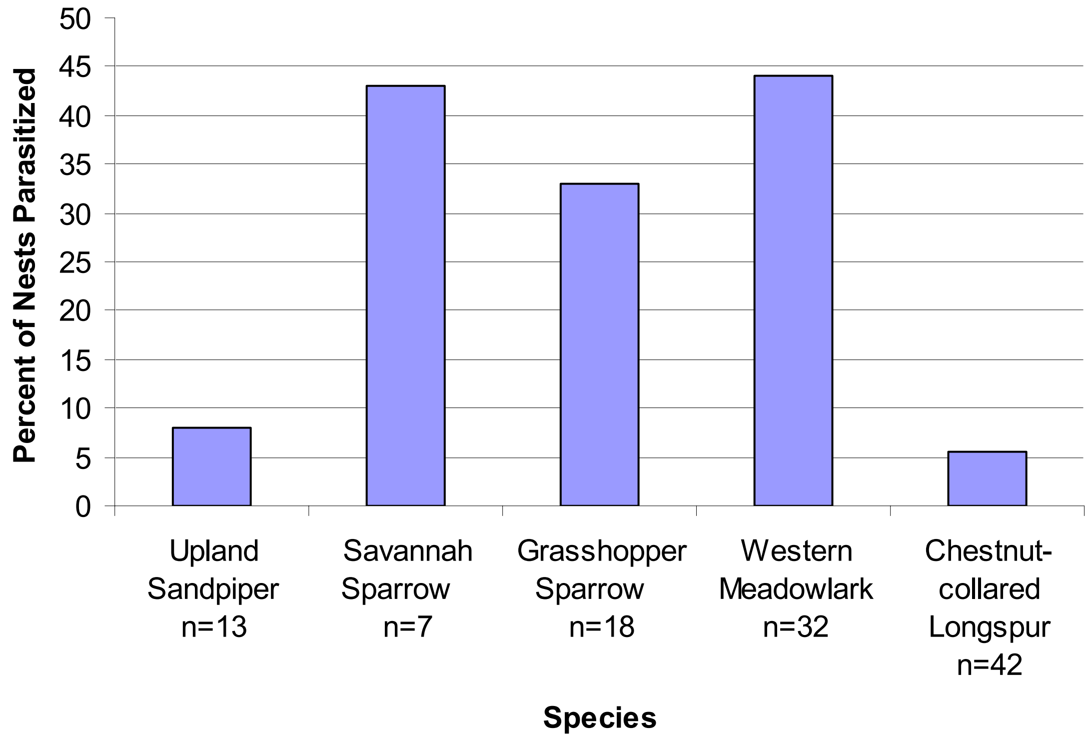

Figure 2. Brown-headed cowbird parasitism rates by species on nests located in native pastures in north central South Dakota, 2004-2005.

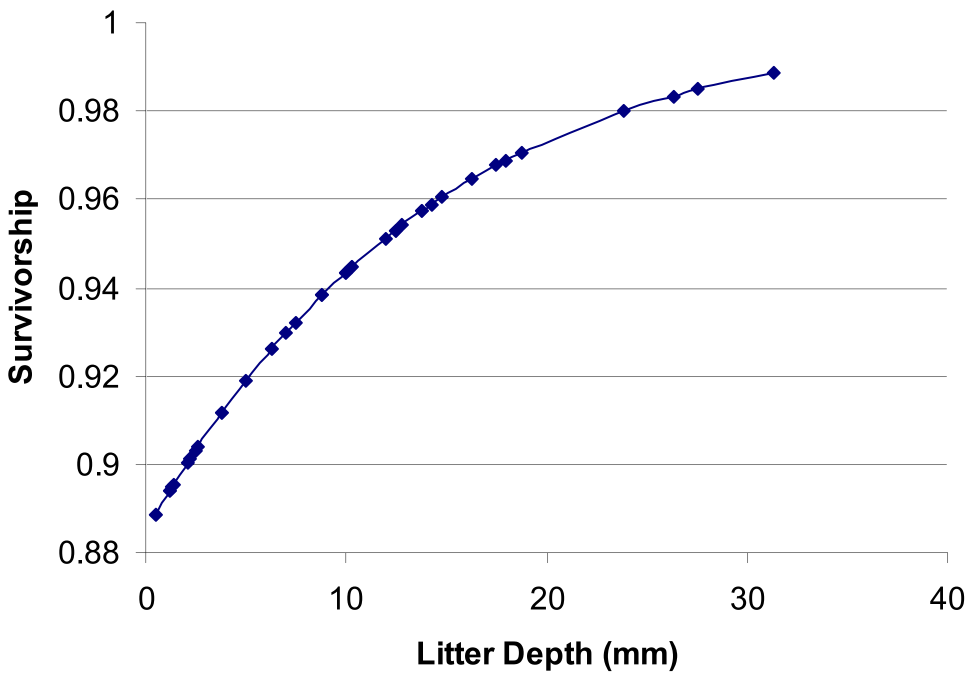

Figure 3. Survivorship of chestnut-collared longspur nests (n=42) increased with increasing litter depth at the nest bowl in native pastures of north central South Dakota, 2004-2005.

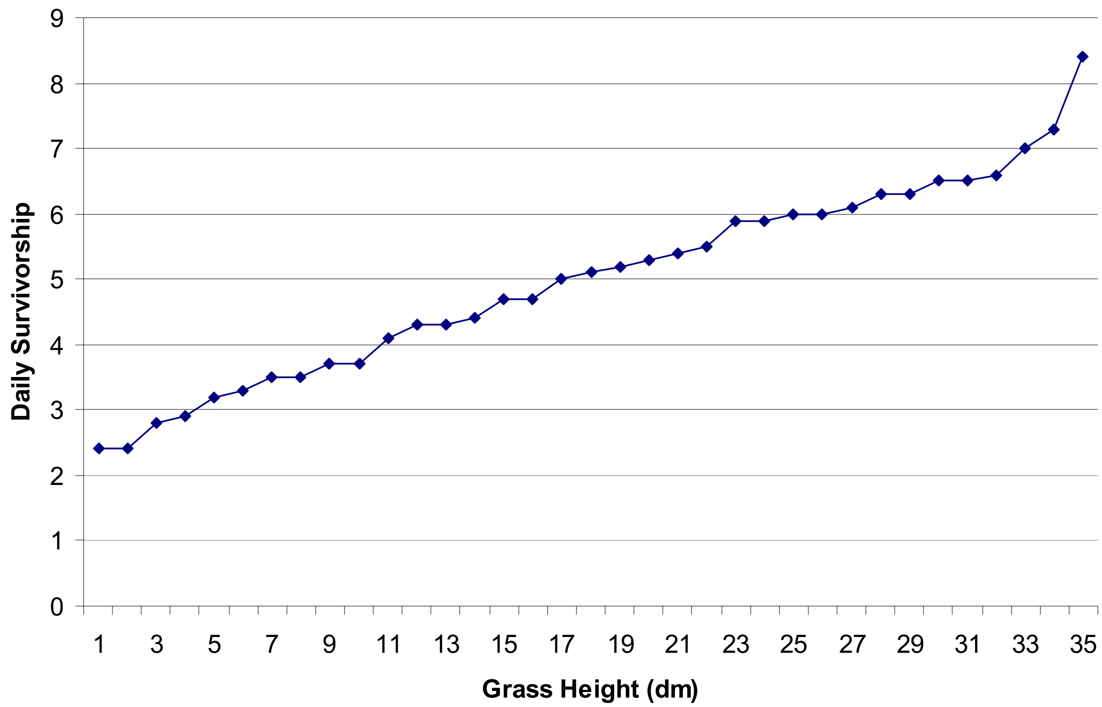

Figure 4. Survivorship of western meadowlark nests (n=32) increased with increasing grass height at the nest bowl in native pastures of north central South Dakota, 2004-2005.

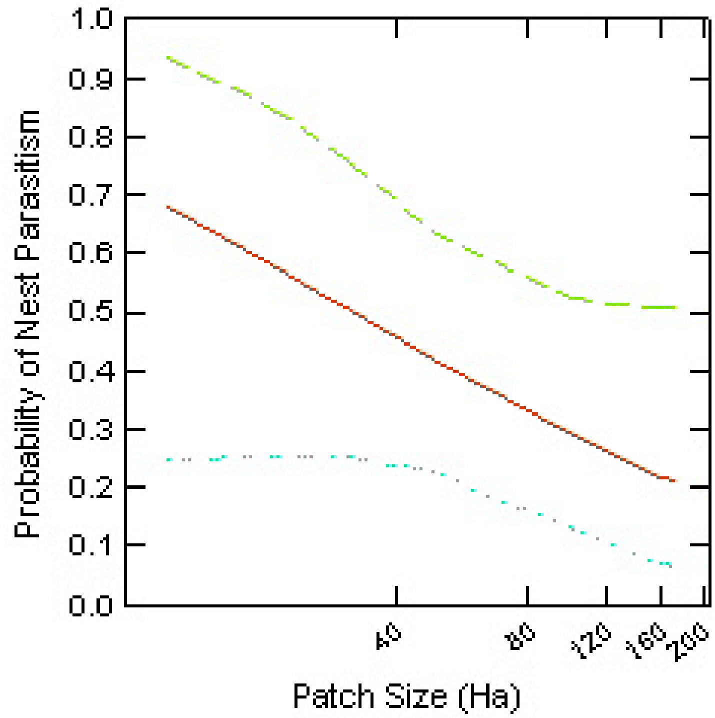

Figure 5. The likelihood of parasitism by brown-headed cowbirds on savannah and grasshopper sparrow nests (n=25) decreased with increasing patch size in native pastures in north central South Dakota, 2004-2005.

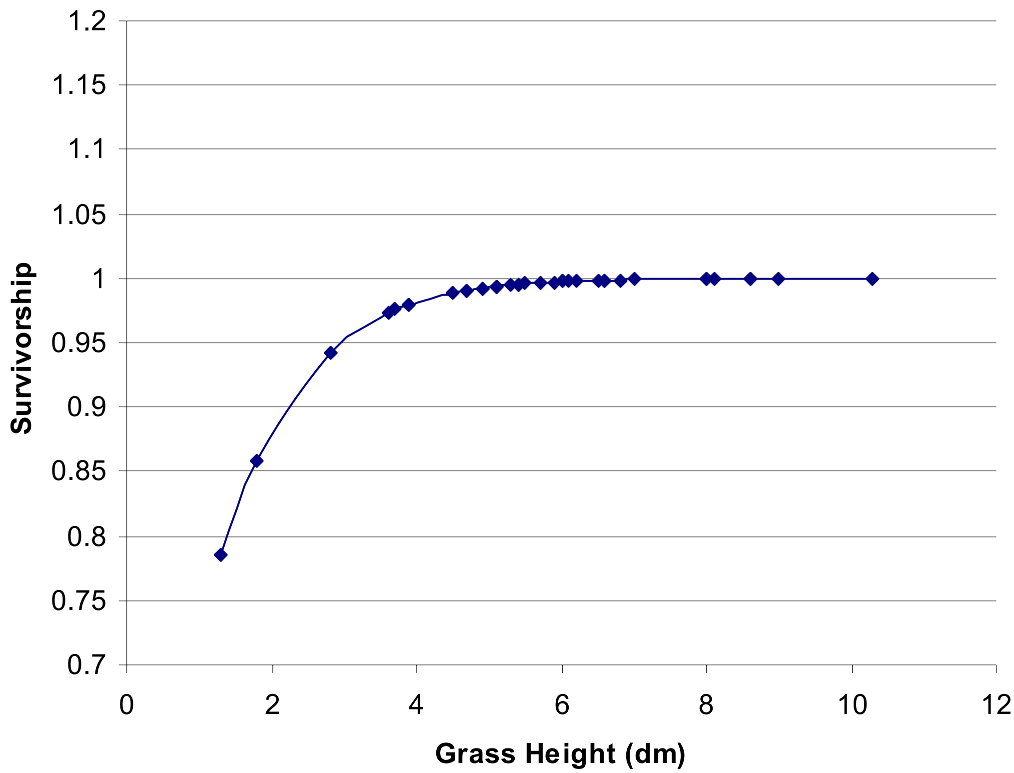

Figure 6. Daily survivorship of dabbling duck nests (n=37) increased with increasing grass height at the nest bowl in native pastures in north central South Dakota, 2004-2005.

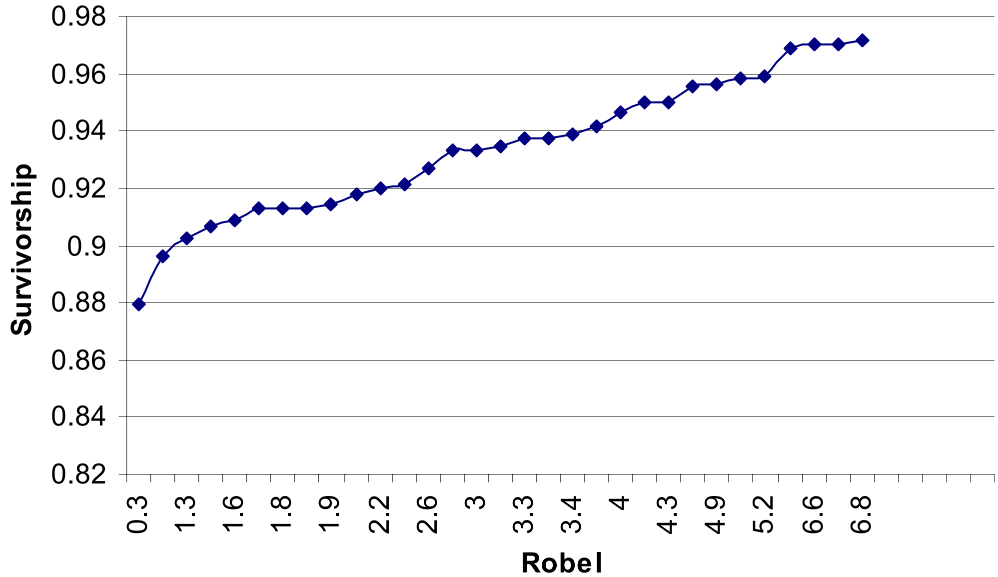

Figure 7. Ring-necked pheasant nest daily survivorship (n=29) increased with increasing Robel measurements (dm) at the nest bowl in native pastures in north central South Dakota, 2004-2005.